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Reference: Technical Progress Report No. 4
Investigation of Lattice and Thermal Stress in GaN/AlGaN Field-Effect Transistors
Period of Performance: 7/1/06 – 9/30/06
Contract # N00014-05-C-0120
RSC DOC# SC71268.RPRTTQ, GO#71268

In accordance with the requirements stated for Contract No. 0014-05-C-0120 entitled "Investigation of Lattice and Thermal Stress in GaN/AlGaN Field-Effect Transistors," enclosed please find Technical Progress Report No. 4 for the above period of performance.

Sincerely,

Karim Boutros
Program Manager

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Table Of Contents

1. Introduction

This report describes work performed in support of the program "Investigation of Lattice and Thermal Stress in GaN/AlGaN Field-Effect Transistors" (Contract No. N00014-05-C-0120) for the period 7/1/06 – 9/30/06.

Our overall goal is to understand the role and contribution of residual stress and junction temperature on the degradation of AlGaN/GaN HEMT electrical device characteristics. To execute this goal, electrical stress measurements will be performed on devices with varying residual stress, and under varying conditions. We plan to use the micro-Raman technique to monitor the evolution of residual stress in the active region of the device over time and under quiescent electrical bias. The question of whether a stress relaxation, potentially inducing dislocations, or simply changing the piezoelectric contribution to the 2DEG charge, contributes to device degradation will be investigated. We will seek to understand the influence of junction temperature on the magnitude of the stress at the active junction. The effect of physical, thermal, and electrical stress on device reliability will be investigated.

2. Progress

2.1. <u>Junction-Temperature Probing</u>

A technique has been developed for thermal resistance measurement of thin film devices using the electrical properties of Schottky contacts on GaN HEMTs. The technique utilizes a sensor device and a heater device in close proximity (20-600μm). An electrical pulse is applied on the heater device generating a heat pulse, which propagates in the semiconductor toward the sensing device. Upon pulsing drain-to-source of the heater device with a power pulse, the gate-source voltage of the sensing device can then provide a measure of the junction temperature rise. By varying the width and the total energy of the heat pulse, we are able to characterize both steady state and transient temperature change in GaN HEMTs. The thermal resistance contribution from the GaN and SiC layers can be modeled using this technique.

We have measured thermal spreading in GaN HEMTs using this technique. Two devices located ~425 microns apart were used as heater and sensor, respectively. Temperatures under the gate of the heater and sensor devices were measured by utilizing the temperature dependence of the forward voltage of the gate-source diode. Fig. 2.1 shows the temperature rise at the sensor device for two different values of the drain-to-source voltage at the heater and at ~100 mA of drain current. The pulse width of the heating pulse was varied from 1 to 5 seconds. The heater and sensor temperatures for a given heat flux is directly related to the local thermal diffusivity. The effective value of the thermal diffusivity is being derived from these data. In particular, the initial rapid rise in temperature within milliseconds is indicative of the thermal diffusivity of the GaN/SiC layer. Preliminary measurements also indicate that the local heater and sensor

temperatures also depend on the electric field concentration under the gate. We are in the process of performing detailed measurements to quantify these results.

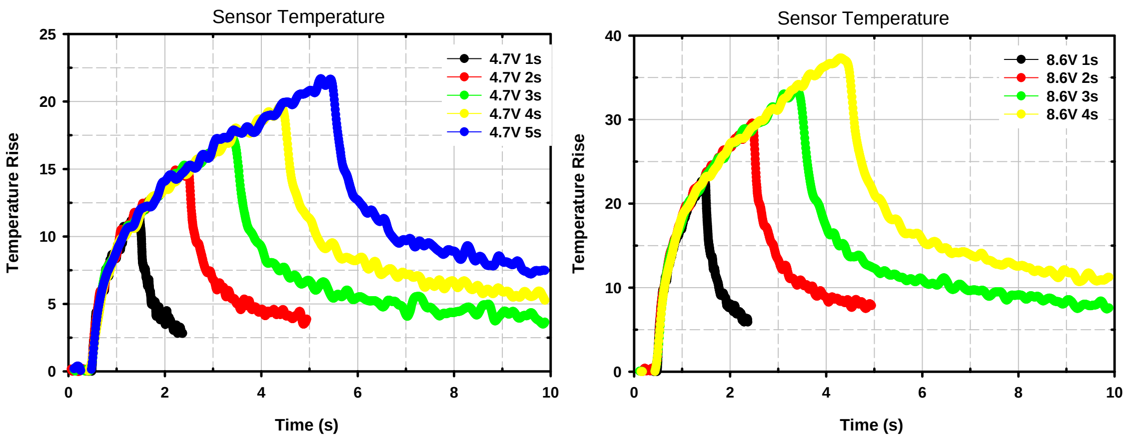

Figure 2.1 Temperature rise above ambient at the gate of the sensor HEMT device located ~425 microns from the heater GaN HEMT device. The drain-to-source pulse width at the heater device is varied from 1-5 seconds for two different values of the drain-to-source voltage (4.7V and 8.6V), while the heater drain current is held constant at ~100 mA.

2.2. Controlled Stress Generation in GaN HEMT Dies

Controlled stress generation in GaN-on-SiC will be used to study the effect of variable physical stress on electrical performance and degradation of GaN HEMTs. To this end, we are constructing a setup, which will be used to apply variable physical stress on GaN die and allow electrical measurements as well as Raman probing of the die under stress. In this period, we have designed and built the required fixture for this experiment.

Given the low load requirements combined with high load accuracy, a system with a voice coil actuator was designed and built to controllably induce the desired amount of stress. A voice coil actuator operates similar to a sound speaker by having a fixed permanent magnet and a mobile coil placed around it. Passing current through the coil will induce a magnetic field and move the coil depending on the direction of the current. The produced force depends directly on the electrical current, as the induced magnetic field is proportional to the current. Reversing the current will reverse the direction of movement.

The test die is mounted in a specially designed package with a cutout on the bottom. A dedicated printed circuit board with a section removed under the package and mechanical attachments for the load frame as well as electrical attachments is used to mount the package. The test frame has been designed to hold the voice coil actuator in a partially extended position allowing for both extension and retraction and thus permitting to apply both tensile and compressive stresses on the specimen. The 3D drawings of the test frame and the package are shown in fig. 2.2. In order to ensure controlled boundary conditions and geometry, the die is soldered along a 1 mm wide strip on two edges parallel to the

test features. The actuator is attached to the die by a thin metal blade, which is glued to the die with the actuator held in neutral position.

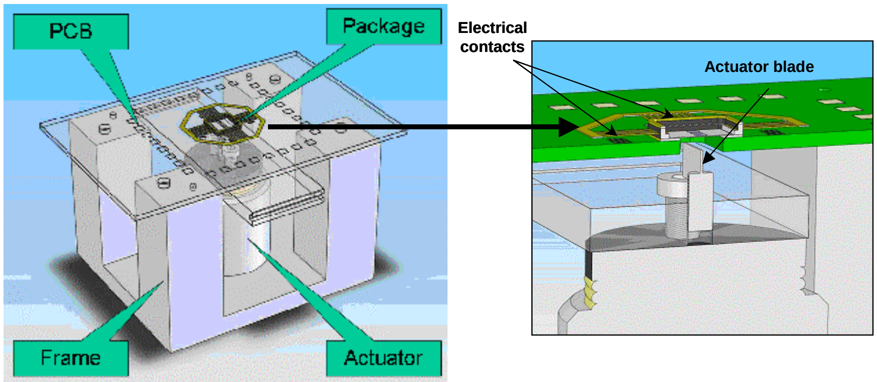

Figure 2.2 3D drawings of the test frame with the package and the test die.

3. Financial Status

Figure 3.1 is a plot of the program's financial status as of August 1st 2006. The actuals are approximately 70% of plan. We expect spending to increase proportional to the increase of labor charge in the next quarter. We are presently funded at $173,000, which is approximately at 70% of the contract value.

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QUARTERLY FUNDS AND MANHOUR EXPENDITURE REPORT NO. 4

				CONTRACTOR:	Rockwell Scientific Company, LLC 1049 Camino Dos Rios Thousand Oaks, CA 91360
CONTRACT NUMBER:	N00014-05-C-0120	DATE PREPARED:	August 16, 2006		
CONTRACT VALUE:	$ 249,963	REPORT PERIOD:	04/29/06 - 07/28/06	PROGRAM MANAGER:	Karim Boutros
FUNDING LIMITATION:	$ 190,000	NUMBER OF LABOR HOURS:	1,072	COMPLETION DATE:	February 15, 2007
FUNDING SPENT:	47%	AMT INVOICED:	$ 88,807	AMT RECEIVED:	$ 81,423

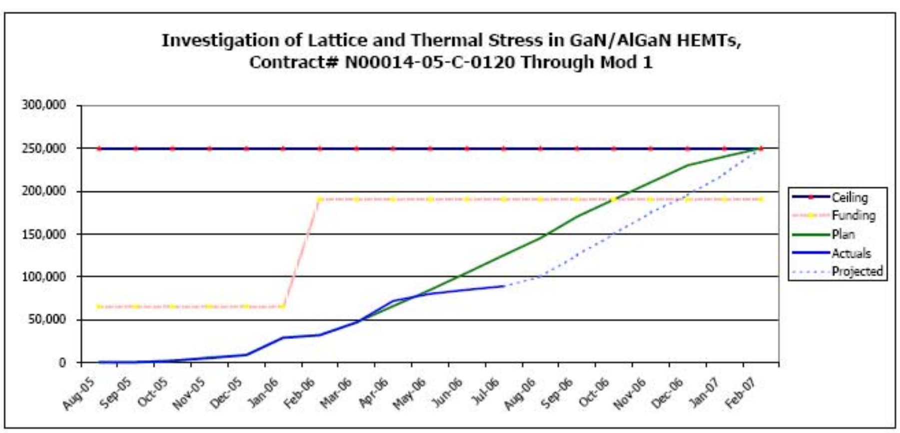

Figure 3.1 Quarterly funds and man-hour expenditure report.

4. Plans for the next quarter

We plan to perform additional measurements using the pulsed temperature probing technique to extract thermal resistance values for GaN-on-SiC devices. We plan to confirm the measurement results using Micro-Raman temperature measurements. We also plan to characterize GaN devices under physical stress and quantify the impact of this stress on the electrical performance, as well as the electrical degradation of GaN devices.